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An evaluation of early lactation foot-trimming in dairy heifers in a randomized controlled trial

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Abstract

Foot trimming is a commonly used tool in lameness prevention in dairy cattle. Despite this, there is surprisingly limited experimental evidence on its efficacy especially in regards to primiparous heifers. A randomised negatively controlled trial was conducted to investigate the association between an early lactation foot-trim on primiparous animals and production outcomes. 282 heifers were enrolled from 8 farms in the UK and randomly assigned to or control groups. Milk yield (305 day adjusted) was not significantly different between groups (trimmed 7727L, untrimmed 7646L). However, multivariate regression analysis demonstrated that this relationship was confounded by lameness state. Animals which were lame at the time of trimming gave significantly more milk (734L p=0.02) than those which were non-lame and untrimmed. Our results suggest that, based on milk production alone, it would not have been cost beneficial to trim all heifers; however a targeted intervention aimed at lame animals would have delivered a substantial return on investment. As a very minimum we recommend heifers should be regularly assessed in early lactation and treated as soon as they are identifiably lame. The high prevalence of lesions identified suggests routine trimming for all heifers may be justifiable on welfare grounds even if the milk yield benefits are marginal.

Introduction

Lameness remains a common condition in the UK dairy herd (Barker and others 2010). Historically much of the management advice provided by vets and consultants has had its roots in expert opinion and a solid evidence base has been lacking (Potterton and others 2012). Efforts to ameliorate this knowledge gap have seen research on the importance of early treatment intervention (Groenevelt and others 2014), improvements in cattle mobility through increased frequency of routine trimming (Manske and others 2002a, Smith and others 2007) as well at studies aimed at improving our understanding of the pathophysiology of lameness lesions, both infectious and claw horn. There is, however, still a lack of understanding of how to prevent or minimise the incidence of claw horn disease in primiparous heifers despite evidence suggesting that they are at an increased risk (Cook and others 2009).

Lameness can be particularly painful in cattle (Whay and others 1998) and has significant effects on production (Archer and others 2010, Huxley 2012). Lame cows have been shown to produce less milk for up to four months before and five months after lesion identification (Green and others 2002), which for some cows may encompass an entire lactation. The magnitude of production loss depends on the type and severity of lesion as well as the effectiveness of any treatment administered (Amory and other 2008). However it has been demonstrated that, even with successful intervention, cows which have gone lame previously are more likely to suffer from lameness in the future (Reader and others 2011), making prevention an important aspect of lameness control.

Previous work investigating the effects of claw trimming found that a singleintervention resulted in lower odds of lameness and claw horn lesions when animals were trimmed and re-examined six months later (Manske and others 2002a). The authors were unable to attribute the reduction to either a preventative or a therapeutic effect as no intermediate examinations were made. This intervention was conducted irrespective of the stage of lactation of the cow. In another study by Hernandez and others (2007), cows which had no previous history of lameness were trimmed at 200 days post calving (cows with previous lameness treatments were excluded). The trimmed group experienced a reduction in lameness incidence (25% vs 18%), but this difference was not significant. While the study conducted by Manske and others (2002a) included nulliparous heifers within two months of calving as well as primiparous heifers, data on these animals was not analysed separately and no conclusions drawn about them.

The aim of the present trial was to evaluate whether a single, foot-trimming intervention of dairy heifers' feet at 50-80 days post calving was beneficial in terms of production parameters during the first lactation.

Materials and Methods

Study design and reporting

A negatively controlled, randomised clinical trial was designed to evaluate the benefit of a single, functional and, if warranted, therapeutic foot trim between 50-80 days post-calving in primiparous Holstein dairy heifers. A function trim was defined as steps 1-3 of the Dutch 5 step method and a therapeutic trim proceeded to steps 4 and 5. The primary hypothesis was that the milk yield of study animals was affected by the trimming intervention. The primary outcome measure was 305 day adjusted milk yield in the lactation in which the intervention took place. The secondary hypothesis was that fertility would be affected by the intervention. The secondary outcome was 100 day in calf rate. 100 day in calf rate is a fertility metric quantifying the proportion of cows, as a percentage, confirmed in calf again to a service within 100 days of the previous calving. Both outcomes were measured at the individual animal level. A cost-benefit calculation estimated that an increase in production of 346L in 305 day yield would be required to generate a 3:1 return on an intervention investment of £15 (approximate cost of a four foot trim). Margin over all feed was used as the primary profitability index; a value of 13 pence per litre (ppl) was used (based on a 25ppl milk price) in the calculation. The sample size required to detect this difference was calculated to be 170 animals in each treatment group (power value = 0.8, P=0.05).

The trial was conducted under the UK Veterinary Surgeons Act 1966 and the protocol was reviewed and approved by the University of Nottingham's School of Veterinary Medicine and Science Ethical Review Committee prior to commencement of the trial. The study manuscript has been prepared in accordance with the guidelines outlined in the REFLECT statement for reporting randomized controlled trials in livestock (O'Connor and others 2010)

Herd selection

A convenience sample of dairy farms with Holstein cows were selected for inclusion in the trial on the basis of their meeting the following criteria: average herd 305d lactation milk yield >8500L (Whole milk); currently conducting routine monthly milk recording; not currently routinely foot trimming heifers post calving; sufficient heifers likely to be available for enrolment over the study period; willingness to participate in the study. Eight farms were identified and recruited through their veterinary surgeons in five practices geographically distributed throughout England. Descriptive information on the enrolled farms is outlined in Table 1.

Randomisation and data collection

Farms were visited every 30 days between July 2013 and March 2014 when suitable heifers were available to be recruited to the study. A list of animal identification numbers of all heifers between 50 and 80 days post partum on the planned visit day was generated prior to the visit. Randomization was blocked by farm; heifers were allocated alternately to each treatment group as their identification numbers were drawn with the first animal on each farm allocated to the treatment(trim) group. In this way the randomisation was performed before the animals had been seen by the operator but in such a way as to ensure an approximately even split of animals assigned to each group on each farm.

The animals were mobility scored over at least eight successive strides on a level concrete surface using the UK industry standard four point system, similar to that originally described by Whay and others (2003). Following mobility scoring heifers were locked into a handling crush and examined for body condition score according to the Penn State University method (Ferguson and others 1994). The heifers assigned to thecontrol group were released from the crush with no further intervention (i.e. their feet were not elevated, trimmed or examined) while those which had been assigned to the treatment group were given a four foot trim. All intervention trimming was carried out using the Dutch five step method based on the method originally described by Toussaint Raven (1989). Each heifer was given a functional trim which progressed to a remedial trim if lesions were identified. Any digital dermatitis lesions were sprayed with oxytetracyline spray (Engemycin Spray

3.84%™, MSD Animal Health). No additional treatments (e.g. non-steroidal anti-inflammatory drugs or application of a foot block) were administered. Any lesions present were noted on data collection sheets and photographs were taken of all feet. Once trimmed all heifers were returned to the feeding areas.

The farmers were all instructed that routine identification and treatment of lame animals should continue as per their normal on-farm practices, however no routine trimming of heifers should be undertaken until the animals were at least 150 days post-partum. All farms involved in the trial housed either all lactating animals or at least the high yielding group all year round. Consequently all enrolled heifers on all farms were housed at the time of, and for at least 70 days following the study intervention.

All eligible heifers were enrolled, i.e. providing they were between 50 and 80 days post-partum no animals were excluded. Randomization, group allocation and all foot trimming was conducted by a single operator (OM), a veterinary surgeon specialised in farm animal work and experienced at cattle foot trimming. Due to the nature of the intervention the operator was not blind to the treatment administered. Farmers were not told which heifer received a trim (i.e. as far as was reasonably possible they were blind to treatment group) however in some cases of heifers with obvious lesions it may have been evident to the farmer which animals had received a trim. No further follow up was conducted with the farms in regards to lameness or mobility score records.

Lesion classification

Lesions identified in treatment group animals were classified into one of six categories:

1. Sole haemorrhage: evidence of historical bleeding from the corium, ranging from a few specks of blood in the sole horn to large areas of haemorrhage
2. Sole ulcer: an area of complete interruption of horn formation
3. White line haemorrhage: evidence of haemorrhage in the white line
4. White line separation: complete separation (with or without infection) of the white line
5. Digital dermatitis: presence of a characteristic lesion
6. Slurry heel: significant erosion to the horn around the heel requiring corrective trimming to remove

Data collation and statistical analysis

Fertility data and milk yields were collected from milk recordings and on farm management systems. Data was collated between May 2013 (the calving date of the first enrolled animal) and November 2014 (the point at which the last animals reached 305 post partum). The data were recorded on data capture sheets and then transcribed into a relational database (Access 2007, Microsoft Corporation). Data was audited for validity and spurious records by manually scanning for outlying data points following sorting within each data category. A small number of errors (<10) were identified and corrected.

Study randomisation was tested by comparing body condition score and mobility score between treatment and control groups using the Mann Whitney U test. Days in milk at enrolment was normally distributed and compared using a two sample T-test. The primary outcome (305 day yield) was compared between groups using a two sample T-test, after testing yield distribution for normality. One hundred day in calf rates were calculated for each group, with proportions compared using a

Chi squared test. The significance probability was set at $P \leq 0.05$ for a two tailed test.

The associations between treatment group and the outcome variables were further tested using multivariate regression analysis. Two regression models were built. Model 1 was designed to investigate associations between treatment intervention and 305 day yield, whilst accounting for potentially confounding associations between milk yield and body condition score, mobility score and herd. Model 2 was a logistic regression model designed to investigate associations between trimming and 100 day in calf rate, whilst accounting for confounding associations between reproduction and body condition score, mobility score, herd and yield. In order to represent the interaction between treatment and lameness status at the time of trimming, these variables were combined into a single variable with four categories (non-lame/trimmed, non-lame/untrimmed, lame/trimmed and lame/untrimmed). Mobility scores 2 and 3 were considered lame and scores 0 and 1 were considered non-lame.

Models were built using forward selection, with variables retained in the model if the magnitude of the coefficient estimate for at least one category of the variable was greater than twice the standard error of the estimate (equivalent to $P \leq 0.05$). Rejected variables were re-offered to the final model and retained if they then met the criteria above. Model assumptions for Model 1 were checked by visual assessment of distribution of heifer-level residual errors to evaluate normality, and assessment of a plot of predicted value versus residual error to evaluate homoscedasticity. Model fit for the logistic regression model (Model 2) was tested using the Hosmer-Lemeshow goodness of fit test. Where model fit criteria were not met, inclusion of additional model terms was considered. Model building and testing was carried out using R 3.1.2 (R Core Team 2014).

Results

Study inclusions and exclusions

The number of heifers recruited for the study fell short of the calculated number required to provide sufficient statistical power. Between July 2013 and March 2014, a total of 281 heifers from 8 farms were enrolled with 139 trimmed and 142 left untrimmed (Farm 1: 22 treatment, 23 control; Farm 2: 12 treatment, 11 control; Farm 3: 7 treatment, 6 control; Farm 4: 21 treatment, 21 control; Farm 5: 39 treatment, 44 control; Farm 6: 16 treatment, 15 control; Farm 7: 10 treatment, 10 control; Farm 8: 12 treatment, 12 control). A total of six animals (one treatment animal on Farm 1 and five treatment animals on Farm 5) were eligible for inclusion, were allocated to a treatment group (without the farmers knowledge) but were not presented on the day of the farm visit. These animals were not enrolled.

No adverse events were noted in any study animals. Sixteen animals were culled before reaching 305 post partum. Of these, 7 were in the treatment and 9 were in the control groups (Farm 1: 2 treatment, 2 control; Farm 2: 1 control; Farm 3: 1 control; Farm 4: 2 treatment; Farm 5: 2 treatment, 3 control; Farm 8: 1 treatment, 2 control). Detailed information on why animals were culled was not collected. These animals were excluded from statistical analysis for the primary study outcome (305 day milk yield); they were included in other analyses as appropriate.

Descriptive results and univariate analysis

Distributions of body condition score, mobility score and days in milk were similar between groups (Table 2, no significant differences), suggesting that randomisation was successful. The 305 day corrected yields of trimmed (n=132) and untrimmed heifers (n=134) were not significantly different; sample means (SD) in the trimmed and control groups were 7727L (1611L) and 7646L (1555L) respectively. One hundred day in calf rates (trimmed 45%, not trimmed 53%) were not significantly different between groups.

Of the animals trimmed(ie the intervention group, n=139), 95% (132 of 139) had some pathology to at least one claw. Sole haemorrhage was most prevalent with 95% (132 of 139) of animals affected. Eighty eight percent (122 of 139) of animals had white line haemorrhage, 19% (26 of 139) slurry heel, 13% (18 of 139) sole ulcers, 11% (15 of 139) digital dermatitis and 6% (8 of 139) white line separation. Only 22% (4 of 18) of those animals with sole ulcers were mobility score 2 and none were score 3, in contrast to 50% (4 of 8) of animals with white line separation which were score 2 or 3. Twenty five percent (4 of 16) of animals with digital dermatitis lesions were mobility score 2, and none were score 3.

Multivariate analysis

Statistically significant associations were found between 305 day adjusted milk yields and mobility score/trimming category, body condition score and herd of origin in Model 1. Heifers which were lame (score 2 or 3) at the time of enrolment and trimmed (n=20) demonstrated an increase in yield of 734L (P=0.02, 95% confidence interval 98-1370L) compared to the reference category (non-lame/untrimmed (n=114)). The other categories (non-lame/trimmed (n=119) and lame/untrimmed (n=28)) were not significantly different from the reference. Parameter estimates for Model 1 are shown in Table 3.

Statistically significant associations were found between the odds of pregnancy occurring by 100 days and mobility score/trimming category and milk yield in Model 2. Heifers which were lame and trimmed (n=20) had significantly lower odds of being in calf by 100 days (P=0.04, odds ratio 0.31, 95% confidence interval 0.10-0.97) compared to the reference category (non-lame/untrimmed (n=114)). The other categories (non-lame/trimmed (n=119) and lame/untrimmed (n=28)) were not significantly different from the reference. Parameter estimates for Model 2 are shown in Table 4. Model fit was satisfactory for Model 1; in the case of Model 2 the herd variable was retained in the model in order to produce a well-fitting model even though no individual herd was significantly different to the reference herd (no inference was made regarding differences between herds).

Discussion

This is among the first randomised negatively controlled clinical trials to investigate the impacts of a timed foot trimming intervention on production in dairy cattle. In this study, heifers were trimmed between 50 and 80 days after calving. Overall there was no difference in 305 day milk yields between groups (sample means: 7727L vs 7646L). A power calculation conducted prior to the study suggested that a sample size of 170 in each group could identify a yield difference of 346L, which would deliver a 3:1 cost benefit ratio over the cost of the intervention. Unfortunately the target sample size was not reached. Across the 281 animals recruited a difference in yield between groups of 81L (7727 vs 7646L) was observed. Even if this yield difference was genuine, it would only be worth £10.53 in additional milk (based on a margin over all feed of 13ppl), less than the cost of the intervention itself (~£15).

Importantly, multivariate regression analysis demonstrated that the relationship between this outcome and trimming was confounded by lameness state. By investigating the interaction with mobility score, this trial identified that animals which were lame at the time of trimming gave 734L more milk over a 305 day lactation than those which were non-lame and untrimmed. Whilst the difference between the lame/untrimmed and the non-lame/untrimmed group was not significant, the model outcome suggested that the lame/untrimmed group also gave 444L more milk over 305 days i.e. our results suggest heifers which were lame between 50 and 80 days post-partum gave more milk than their non-lame counterparts. This supports other studies (Archer and others (2010), Green and others (2002)) which demonstrated that lameness is a disease associated with higher yield. However the fact that only the lame/trimmed group showed a significant difference in yield from the non-lame/untrimmed group suggests that trimming had a positive effect and partly mitigated the impact of being lame. Based on a margin over all feed of 13ppl, the increase in yield of 734L in the lame/trimmed group would be worth £95.42; a cost benefit ratio of 6.4:1.Even if it is assumed that the increase in yield seen in the lame/untrimmed group is real and the actual benefit of a trim intervention is only 290L (734L – 444L), this would still be worth £37.70 or a cost benefit ratio of 2.5:1. Since this trial commenced, new evidence supporting additional treatment in newly lame cattle with claw horn lesions has been presented (Thomas and others 2015, submitted for publication). The study demonstrated that lameness cure was significantly improved by the application of blocks to the sound claw and the administration of a course of non-steroidal anti-inflammatory drugs in addition to a therapeutic trim. Had the lame heifers in this trial been treated according to this protocol, further improvements in milk yield may have been seen.

The premise underlying this trial was that by trimming heifers' feet early in lactation the claw horn lesion disease complex could be halted early in its course and the progression to severe disease manifestations (e.g. sole ulcer) and their impact on production prevented. Heifers in the treatment group in this study demonstrated a high prevalence of foot pathology; 95% of animals showing some damage to at least one claw and 13% of heifers were found to have at least one sole ulcer on the eight claws examined. Given the nature of the randomisation there is no reason to suspect that the prevalence of lesions in the control group would be significantly different although this remains possible. This level of pathology in early lactation supports the evidence that claw horn damage is associated with the peri-parturient period (Tarlton and others 2002). Despite the high levels of foot pathology identified, only 16% of heifers were identifiably lame on the day of inspection, in line with UK average figures for all ages and stages of lactation according to Rutherford and others (2009), but markedly lower than the levels identified by Barker and others (2010). The poor correlation between visual foot pathology and lameness have been reported previously (Manske and others 2002b). It is not unreasonable to hypothesise that many of the animals identified with claw horn lesions were in the pre-lame lag phase of disease (i.e. disease would continue to progress to a more severe manifestation or relatively advanced disease was already present but animals had not yet become lame). However other reason contributing to this poor correlation could be related to experience of the scorer and the method of scoring. The lack of yield difference observed between groups may be because the trimming intervention was timed too late to prevent claw horn lesions developing. Work conducted by

Green and others (2002) has demonstrated that in cases of sole ulcer, yield depression can occur from as much as four months before the identification of lameness. This, together with the high prevalence of pathology found during trimming, suggests that for trimming to be effective as a preventative intervention it may have to take place earlier in the production cycle, possibly prior to first calving.

Our results suggest that, based on milk production alone, it would not have been cost beneficial to trim *all* heifers in early lactation; however a targeted intervention aimed at identifiably lame heifers would have delivered a substantial return on investment. These results highlight the importance of early detection of lameness; as a very minimum we recommend heifers should be regularly mobility scored in early lactation and treated as soon as they are identifiably lame. As only production parameters were investigated we have no information on whether further cases of lameness (and their associated impacts on welfare) were prevented without having noticeable impacts on milk yield. Consequently a routine trimming intervention for all heifers may be justifiable on welfare grounds alone even if the milk yield benefits are marginal.

In the univariate analysis there was no significant difference in the 100 day in calf rates between groups, although it must be noted that the study was not powered to investigate this difference. In the multivariate model, animals that were lame and trimmed had significantly lower odds of being in calf than animals that were non-lame and untrimmed. Whilst both non-lame/trimmed groups and lame/untrimmed groups also had lower odds, the differences were not significantly different from the non-lame/untrimmed reference category. These results suggest that the impacts of being lame and being trimmed had a cumulative negative impact on fertility, the relative importance of these two factors cannot be established. The intervention in this study took place between 50 and 80 post partum, at the time when these animals were likely to be being observed for oestrus and inseminated. It is possible that the act of foot trimming a lame cow which is already hyperalgesic (as demonstrated by Whay and others (1998)) caused a temporary reduction in oestrus expression or made animals less likely to conceive. Whilst this finding is of concern, further work is warranted to investigate the impact of trimming around this time more fully. In this context 100 day in calf rate could be considered a blunt indicator of fertility performance as it is based on a binary outcome around the time most animals are expected to conceive. Consequently an extension of the average calving to conception interval of just a few days could push considerable numbers of animals over the 100 day threshold, artificially magnifying the apparent impact of a small decrease in fertility.

The study population was a convenience sample drawn from herds with milk yields above the UK average. Whilst we have no reason to believe that they were not representative of the more intensive production systems common in the UK our results may not be generalizable to heifer managed under other less intensive systems. This is especially true given the arguments we have alluded to around lameness being a condition associated with higher yield. The outcomes assessed in this study were restricted to indirect measures of intervention success (i.e. yield and fertility parameters) due to financial constraints. This approach is justifiable as these outcomes are two of the key drivers of farm profitability and because an additional management intervention such as the one tested here needs to be cost beneficial in order for many farmers to consider implementing it. A more complete picture would have been provided with routine mobility score data and subsequent lameness incidence. This would have allowed inferences to be made on the effect of trimming on lesions and lameness rather than just production parameters and could have enhanced the welfare arguments we outline. This study is one of the first controlled clinical trials to investigate the impact of a routine trimming intervention. Given that foot trimming is commonly practiced around the world, further trials are urgently required to improve our understanding of how trimming impacts on claw health and production parameters, and to determine the most beneficial time to apply the intervention.

Conclusion

In conclusion, this trial demonstrated that based on milk production alone, it was not cost beneficial to trim all heifers in early lactation. However a targeted intervention aimed at lame heifers would have delivered a substantial return on investment. As a very minimum we recommend heifers should be regularly mobility scored in early lactation and treated as soon as they are identifiably lame. Trimming all heifers in early lactation may be justified to limit disease progression in animals early in the course of claw horn disease. The negative impacts of foot trimming heifers on fertility is of concern and in need of further investigation to ensure that these impacts do not outweigh the benefits of early intervention and effective lameness treatment.

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Conflict of interest declaration

The authors have not identified any conflicts of interest with any aspect of the reported study.

References

AMORY, J. R., Z. E. BARKER, ET AL. (2008) Associations between sole ulcer, white line disease and digital dermatitis and the milk yield of 1824 dairy cows on 30 dairy cow farms in England and Wales from February 2003-November 2004. Preventive Veterinary Medicine **83**, 381-391.

ARCHER S.C., GREEN M.J., HUXLEY J.N. (2010) Association between milk yield and serial locomotion score assessments in UK dairy cows. Journal of Dairy Science **94,** 4045–4053

BARKER Z.E. , LEACH K.A., WHAY H.R., BELL N.J., MAIN D.C.J. (2010) Assessment of lameness prevalence and associated risk factors in dairy herds in England and Wales. Journal of Dairy Science **93**, 932–941

BICALHO, R. C., MACHADO V. S., CAIXETA L. S., (2009) Lameness in dairy cattle: a debilitating disease or a disease of debilitated cattle? A cross-sectional study of lameness prevalence and thickness of the digital cushion. Journal of Dairy Science **92**, 3175-3184.

COOK N. B., NORDLUND K. V. (2009) The influence of the environment on dairy cow behaviour, claw health and herd lameness dynamics. The Veterinary Journal **179,** 360–369

GREEN L.E., HEDGES V.J., SCHUKKEN Y.H., BLOWEY R.W., PACKINGTON A.J. (2002) The impact of clinical lameness on the milk yield of dairy cows. Journal of Dairy Science **85**, 2250–2256

GROENEVELT M., MAIN D.C., TISDALL D., KNOWLES T.G., BELL N.J. (2014) Measuring the response to therapeutic foot trimming in dairy cows with fortnightly lameness scoring. Veterinary Journal **201**, 283-288.

HERNANDEZ, J. A., GARBARINO, E. J., SHEARER, J. K., RISCO, C. A., & THATCHER, W. W. (2007). Evaluation of the efficacy of prophylactic hoof health examination and trimming during midlactation in reducing the incidence of lameness during late lactation in dairy cows. Journal of the American Veterinary Medical Association **230**, 89-93

HOLZHAUER, M., HARDENBERG C., BARTELS C. J. (2008). Herd and cow-level prevalence of sole ulcers in The Netherlands and associated-risk factors. Preventive Veterinary Medicine **85**, 125-135.

HUXLEY, J.N., (2012). Lameness in cattle: an ongoing concern. Veterinary Journal **193**, 610-611.

MANSKE T., HULTGREN J., BERGSTEN C. (2002a) The effect of claw trimming on the hoof health of Swedish dairy cattle. Preventive Veterinary Medicine **54**, 113–129.

MANSKE, T., HULTGREN, J., & BERGSTEN, C. (2002b). Prevalence and interrelationships of hoof lesions and lameness in Swedish dairy cows. Preventive veterinary medicine, **54**, 247-263.

O'CONNOR, A.M., J.M. SARGEANT, I.A. GARDNER, J.S. DICKSON, M.E. TORRENCE, C.E. DEWEY, I.R. DOHOO, R.B. EVANS, J.T. GRAY, M. GREINER, G. KEEFE, S.L. LEFEBVRE, P.S. MORLEY, A. RAMIREZ, W. SISCHO, D.R. SMITH, K. SNEDEKER, J. SOFOS, M.P. WARD, AND R. WILLS. 2010. The REFLECT statement: Methods and processes of creating Reporting Guidelines For Randomized Controlled Trials for livestock and food safety. Preventive Veterinary Medicine. **93**,11–18.

POTTERTON, S.L., BELL, N.J., WHAY, H.R., BERY, E.A., ATKINSON, O.C., DEAN, R.S., MAIN, D.C., HUXLEY, J.N. (2012) A descriptive review of the peer and nonpeer reviewed literature on the treatment and prevention of foot lameness in cattle published between 2000 and 2011. Veterinary Journal **193**, 612-616.

R Core Team (2014). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org.

RABER M., LISCHER C. J., GEYER H,. OSSENT P. (2004). The bovine digital cushion - a descriptive anatomical study. Veterinary Journal **167**, 258-264.

RAVEN, E. T. (1989) Trimming. Cattle footcare and claw trimming. 2nd edition. Farming press Ltd. pp75-91.

READER J.D., GREEN M.J., KALER J., MASON S.A., GREEN L.E. (2011) Effect of mobility score on milk yield and activity in dairy cattle. Journal of Dairy Science **94**, 5045–5052

RUTHERFORD K. M.D., LANGFORD F. M., JACK M. C., SHERWOOD L., LAWRENCE A. B., HASKELL M. J. (2009) Lameness prevalence and risk factors in organic and non-organic dairy herds in the United Kingdom. The Veterinary Journal **180**, 95–105

SMITH, B. I., KRISTULA M. A. (2007). Effects of frequent functional foot trimming on the incidence of lameness in lactating dairy cattle. Bovine Practitioner **41**, 138-145.

TARLTON, J.F., HOLAH, D.E., EVANS, K.M., JONES, S., PEARSON, G.R., WEBSTER, A.J., (2002). Biomechanical and histopathological changes in the support structures of bovine hooves around the time of first calving. Veterinary Journal **163,** 196-204

WHAY H.R., WATERMAN A.E., WEBSTER A.J.F., O'BRIAN J.K. (1998) The influence of lesion type on the duration of hyperalgesia associated with hindlimb lameness in dairy cattle Veterinary Journal **156**, pp23–29

Table 1: Descriptive information of participating farms in a trial designed to test a foot trimming intervention in first lactation dairy heifers

Farm	Approximate number of adult dairy cows	Approximate herd average 305 day milk yield (L)	Calving pattern
Farm 1	400	10,000	Year round
Farm 2	550	9,800	Year round
Farm 3	450	9,500	Year round
Farm 4	320	9,500	Year round
Farm 5	300	9,500	Year round
Farm 6	250	9,000	Autumn
Farm 7	300	9,000	Autumn
Farm 8	350	10,000	Year round

Table 2: Distribution of key parameters for the sample population in a trial designed to investigate a foot trimming intervention in first lactation dairy heifers

	Body Condition Score					Mobility Score				Days in Milk
	2	2.5	3	3.5	4	0	1	2	3	
Treatment Group	7 (5%)	64 (46%)	48 (35%)	15 (2%)	5 (4%)	29 (21%)	90 (65%)	19 (14%)	1 (1%)	64.7
Control Group	14 (10%)	56 (39%)	54 (38%)	17 (12%)	1 (1%)	41 (29%)	73 (51%)	28 (20%)	0	65.6
Total (Total %)	21 (7%)	120(48%)	102 (36%)	32 (11%)	6 (4%)	70 (25%)	163 (58%)	47 (17%)	1 (1%)	65.2

Table 3: Parameter estimates for a model with the outcome of 305 day adjusted milk yield (Model 1) in a trial designed to investigate a foot trimming intervention in first lactation dairy heifers

Model term	Coefficient (95% CI)	p-value
Intercept	6795	
Non-lame/untrimmed	Reference	
Non-lame/trimmed	144 (-189 to 477)	0.39
Lame/untrimmed	444 (-124 to 1012)	0.12
Lame/trimmed	734 (98 to 1372)	0.02
BCS≤2.5	Reference	
BCS>2.5	-554 (-876 to -233)	0.001
Herd 1	Reference	
Herd 2	659 (-6 to 1324)	0.05
Herd 3	943 (130 to 1757)	0.02
Herd 4	517 (-36 to 1072)	0.06
Herd 5	2081 (1603 to 2560)	<0.001
Herd 6	87 (-517 to 692)	0.77
Herd 7	658 (-181 to 336)	0.05
Herd 8	2332 (1664 to 3000)	<0.001

Table 4: Parameter estimates for a model with the outcome representing odds of pregnancy occurring by 100 days post calving (Model 2) in a trial designed to investigate a foot trimming intervention in first lactation dairy heifers

Model term	Coefficient	p-value	Odds Ratio (95% CI)
Intercept	1.70		
Non-lame/untrimmed	Reference		
Non-lame/trimmed	-0.36	0.19	0.70 (0.41 to 1.21)
Lame/untrimmed	-0.33	0.45	0.72 (0.30 to 1.75)
Lame/trimmed	-1.17	0.04	0.31 (0.10 to 0.97)
305 day milk yield (‘000L)	-0.19	0.03	0.83 (0.76 to 0.90)
Herd 1	Reference		
Herd 2	-0.63	0.25	0.50 (0.18 to 1.59)
Herd 3	0.29	0.67	1.33 (0.35 to 5.08)
Herd 4	-0.32	0.48	0.73 (0.30 to 1.78)
Herd 5	0.55	0.20	1.73 (0.74 to 4.05)
Herd 6	0.12	0.80	1.13 (0.43 to 2.98)
Herd 7	-0.64	0.27	0.53 (0.17 to 1.66)
Herd 8	-0.58	0.32	0.56 (0.18 to 1.80)